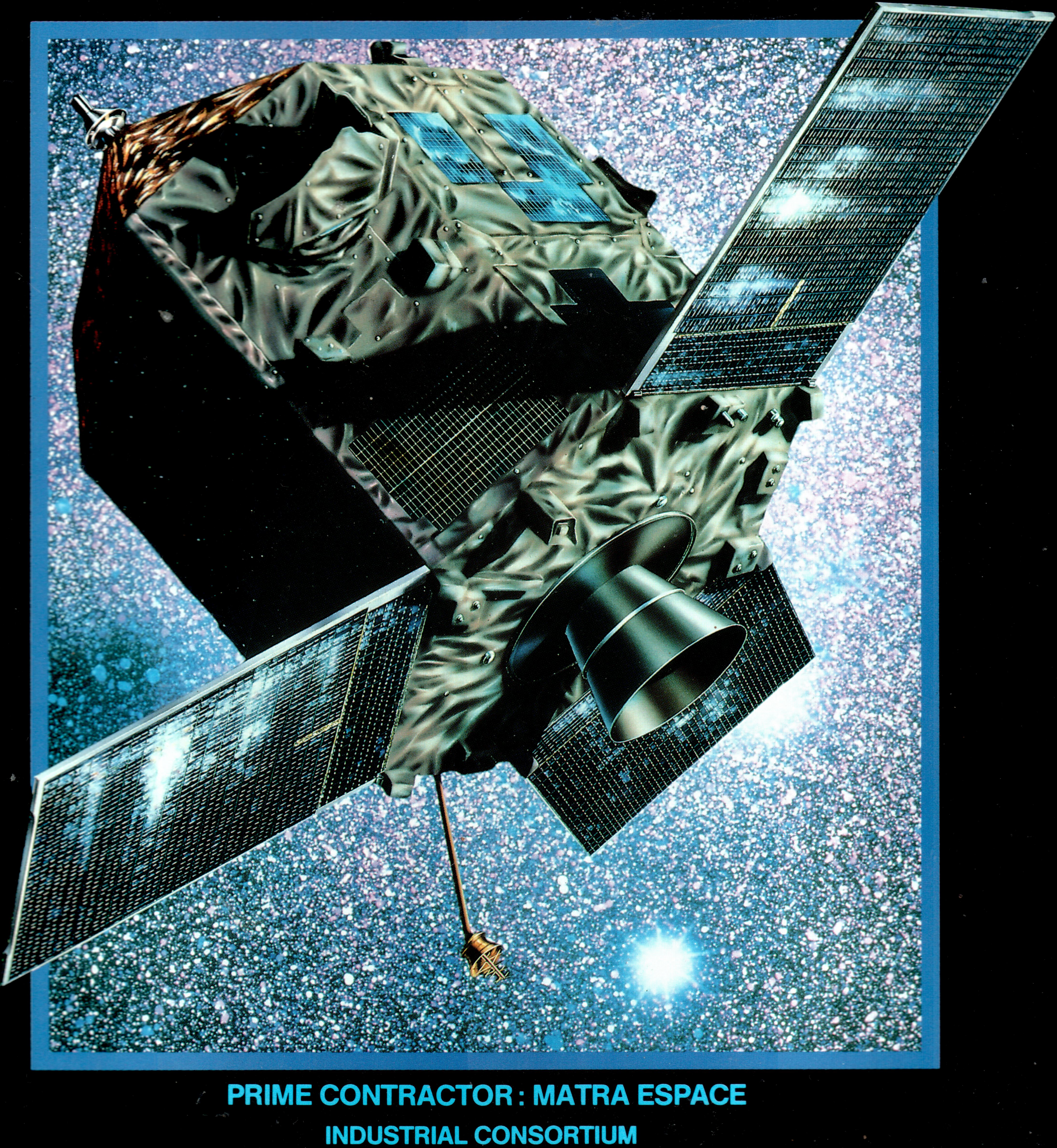
HIPPARCOS

THE EUROPEAN SPACE AGENCY'S ASTROMETRY MISSION



PRIME CONTRACTOR : MATRA ESPACE

INDUSTRIAL CONSORTIUM

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HIPPARCOS: Astrometry from Space

Why an Astrometry Mission?

The only direct way of determining the distance to a star is by measuring its 'trigonometric parallax', the apparent movement of the star observed as the Earth moves in its annual orbit around the Sun. In spite of the fact that this apparent motion, even for the nearest stars, is extremely small, most of the key physical characteristics of a star can only be determined once the distance to the star has been measured or estimated. The very precise measurement of stellar positions also yields a reference frame, important for many scientific studies, and details of how the stars move through space, important for any understanding of our Galaxy's motion and evolution.

Hipparcos is the European Space Agency's astrometry mission, a space experiment dedicated to the precise measurement of the positions, parallaxes and proper motions of the stars. ESA undertook a feasibility study of the project at the end of the 1970's, and this led to the adoption of the mission as part of the Agency's scientific programme in 1980. The hardware development began early in 1984, the satellite was completed and placed in storage in May 1988, and is now due for launch by Ariane 4 (Flight 33) on 25 July.

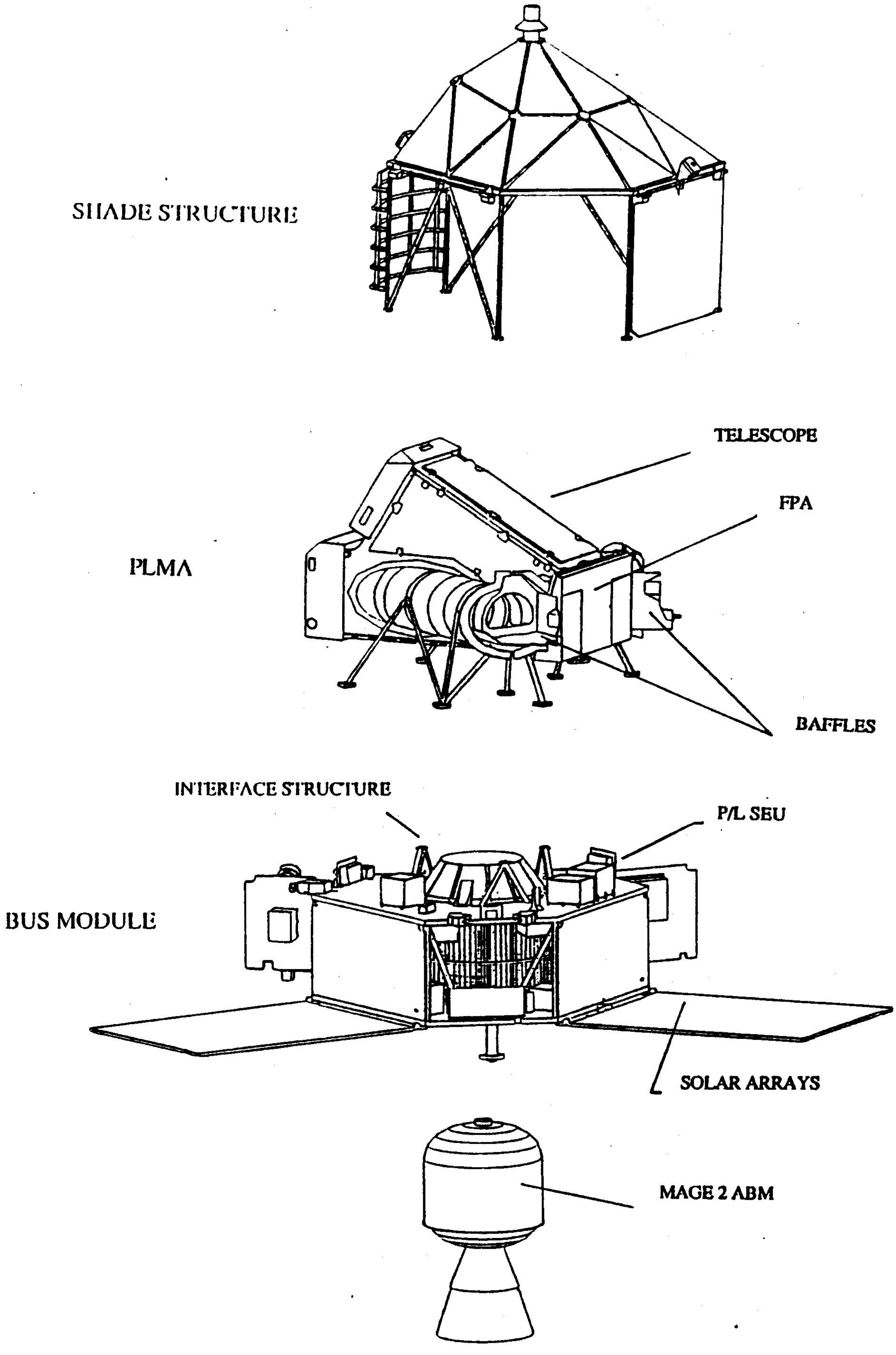
How will Hipparcos map the Stars from Space?

What makes Hipparcos so unique, and the expected results so dramatic, is the all-sky visibility of the satellite, combined with the absence of a perturbing atmosphere, and the instrumental stability brought about by the absence of gravitational instrumental flexure as well as a stable thermal environment. Differential angular measurements are made over large angles, at many different orientations, and at many different times.

The satellite is designed to spin slowly, sweeping out great circles across the sky, and completing a rotation in just over two hours. At the same time it can be controlled so that there is a slow changing of direction of the axis of rotation. In this way the telescope will be able to scan the complete celestial sphere.

By these measurements, the instrumentation is continually comparing the relative positions of the programme stars which will appear first in the preceding field of view and then in the following field of view due to the rotation of the satellite. In this way several comparisons with different stars can be made. As the scans also overlap 'sideways' when the satellite axis of rotation changes on each sweep of the sky, the stars will appear again, but this time compared with other stars. In this way, a dense net of measurements of the relative separation of the stars is slowly built up.

The Hipparcos payload is centered around an optical all-reflective Schmidt telescope. The light from two sections or 'fields' of the sky is conveyed through two baffles which are set at a fixed angle of about 58°. A 'beam combiner' allows the two fields, which are viewed simultaneously, to be projected onto the spherical primary mirror. It is then possible to determine the true angle



An exploded view of the Hipparcos satellite

between two stars, one in each field of view, by using the known or 'basic angle' of 58° between the two fields of view, plus the apparent separation measured on the focal surface of the telescope.

The focal surface on which the two fields of view are focussed contains 2688 parallel slits in an area of 2.5×2.5 cm^2. As the telescope slowly scans the sky, the star light is modulated by the slit system, and the modulated light is sampled by a an image dissector tube detector, at a frequency of 1200 Hz. At any one time some four or five of the selected (or programme) stars will be present in the two fields of view. The detector has a small sensitive area, referred to as the instantaneous field of view, covering an area of about 38 arcsec in diameter (projected on the sky). The detector can only follow the path of one star at a time, but under rapid computer control it is able to track all the programme stars for short intervals of time during their passage across the field, which takes about 20 seconds.

Hipparcos will Observe each Star about 80 times during its Lifetime

In order to carry out the scanning of the sphere, the satellite spin axis will be kept at a constant inclination of approximately 43° to the direction of the Sun, and will revolve around the Sun once in about eight weeks, resulting in a continuous and systematic scanning of the celestial sphere. The scanning motion is described further below. Any region of the sky will be scanned many times during the mission by great circles which intersect at well-inclined angles. An average star will be observed some eighty times throughout the nominal lifetime of the satellite. The number of possible connections between the observed stars will have been considerably enhanced due to the almost simultaneous observation of stars separated by the large basic angle. Astronomers in charge of the data analysis will then combine the individual measurements to form the final Hipparcos Catalogue, including the displacements due to parallax and proper motion, using techniques similar to those used in triangulation in surveying the Earth's surface.

The Star Mapper will Measure Another 400 000 Stars

In addition to the main instrument, the payload includes two star mappers, one of which is normally switched off and is provided as a spare channel. The function of the star mapper is to provide data allowing real-time satellite attitude determination, a task performed on-board the satellite, and the *a posteriori* reconstruction of the attitude, a task carried out on the ground. The star mapper data is also used by the Tycho experiment to perform astrometric and two-colour photometric measurements of about 400 000 stars down to about 10–11 mag.

Each star mapper consists of a special grid located at the side of the primary modulating grid, and two photomultipliers measuring the light transmitted by the whole star mapper grid in two different spectral bands, roughly corresponding to the Johnson B (blue) and V (visual) bands. The spectral separation is performed by means of a dichroic beam splitter which directs the transmitted light of one colour onto one of the photmultiplier tubes, and the reflected light of another colour onto the second tube. Each star mapper consists of two sets of four slits, each set at different inclinations with respect to the scanning direction, so that the satellite attitude can be derived from the photomultiplier signals as the star images move across the grid. The modulated light signal is converted into photon counts by the two photomultiplier tubes, which are sampled at a frequency of 600 Hz.

The Star Observing Strategy

At focal plane level the result is a continuous flow of stars from both viewing directions. Each star crosses the field of view of the telescope in 19.2 seconds, and four programme stars, on average, are in the combined field of view at any time. The grid modulates the light of each crossing star, which is then collected by an image dissector tube and converted into photoelectron counts. The sequence of photoelectron counts obtained during the transit of star can be used to derive its phase. From the phase difference of two stars observed almost simultaneously in the field of view, their angular distance can be derived.

Since only one star can be followed at a time, strictly simultaneous observation of two stars is not possible. Quasi-simultaneous observations are, in practice achieved by switching very frequently the instantaneous field of view from one star to another following a predefined scheme.

The scheduling policy used to reposition the instantaneous field of view this way and allocate the observation time to the various stars is, in the Hipparcos terminology, called the star observation strategy. The star observing strategy algorithm, implemented in the on-board computer, selects at regular time intervals among the programme star which cross the field of view those which have to be observed, and allocates to them appropriate observation times.

All mission operations will be conducted from the European Space Agency's ground station at the European Space Operations Centre (ESOC) in Darmstadt. The ground station will uplink segments of the Input Catalogue, referred to as the programme star file, and this information will control both the observations and the scanning motion of the satellite. Data sent down from the satellite will be monitored, merged with auxiliary parameters such as satellite orbit information, and despatched to the data reduction consortia for subsequent processing.

The Hipparcos Input Catalogue

The limiting magnitude of the observations is expected to be about $V = 12.4$ mag. But, due to the scanning motion of the satellite, there isn't enough time to observe all stars down to this magnitude limit. Consequently some selection of programme stars has had to be made. Essentially, all stars down to a magnitude limit of between 7–9 mag (depending on spectral type and galactic latitude) will be observed (i.e. the star survey will be complete to this magnitude limit), along with about 40 000 stars between the completeness limit and the faintest magnitudes observable by the satellite.

The precise observing programme will be based on the so-called *Hipparcos Input Catalogue*, compiled by a consortium of scientific institutes. The Input Catalogue Consortium is responsible for the processing of the scientific observational proposals and the construction of the corresponding programme of observations according to priorities set by the Selection Committee, and according to the technical constraints of the satellite observations. This work has involved detailed mission simulations which have allowed the distribution of programme stars on the sky, and their allocated observing times to be optimised. The Input Catalogue has now been implemented in ESOC where, in the form of the programme star file, subsets will be uplinked at regular intervals to the satellite, depending on the known and predicted satellite attitude over the coming hours.

To ensure that the *a priori* data are of adequate quality for the satellite observations, the Input Catalogue Consortium has complemented available data with cross-identifications, extensive

ground-based astrometric and photometric observations, and detailed work on particular categories of objects. The latter include double and multiple stars (where extensive re-measurements and cataloguing has been necessary) minor planets (important for a definition of the dynamical reference system), large-amplitude variable stars (where a more precise knowledge of their ephemerides is necessary in order to allocate the appropriate amount of observing time to them), photometric standards, and objects for a link to the extragalactic reference frame.

Production of the Hipparcos Star Catalogue

The satellite will produce some 24 kbits of data per second, mostly image dissector tube data and two-colour data from the star mapper. Thus about 10^{12} bits of data will be generated over the satellite lifetime of 2.5 years, corresponding to the measurement of some 150×10^6 grid coordinates. These data will be analysed to yield approximately $5 \times 120\ 000 = 600\ 000$ astrometric star unknowns. In the reduction process some 10^6 attitude unknowns and some 20 000 instrumental unknowns, essentially the time-, position- and colour-dependent coefficients entering the field-to-grid transformation representation, are either eliminated or solved for.

The problem is essentially one of solving a very large and very sparse set of equations with a very large number of unknowns—too large to be treated in any direct manner. Even after the elimination of the attitude unknowns, the system would still contain about 100 Gbytes of data, and a direct solution would still be out of the question.

The problem lends itself, however, to a form of linear decomposition by the formation of certain intermediate quantities—the star abscissae along the great circles swept out by the scanning motion of the satellite. While more rigorous solutions to the problem of the attitude and sphere reconstruction are still being studied, both data reduction consortia have adopted, as their baseline, the decomposition into three stages, the so-called 'three-step' solution. The constituent steps of the three-step method have been studied, documented, programmed and simulated intensively by the two data reduction consortia since the method was introduced.

The two teams responsible for the processing of the main Hipparcos data are the Northern Data Analysis Consortium (NDAC) and the Fundamental Astronomy by Space Techniques (FAST) Consortium. The involvement of the two consortia, who use slightly different techniques, should ensure a proper confidence in the validity of the final results.

The data reductions proceed as follows:

Step 1: the image dissector tube photon counts are extracted from the data stream, disentangled from the interleaving created by the 'star observing strategy' generated by the on-board computer according to the pattern of stars visible within the combined fields of view, and fitted to a 3- or 5-parameter star intensity model. A reference great circle, of about 12-hour duration, is selected with celestial pole close to the mean position of the instrument's spin axis over this period, then the star abscissae, the along-scan attitude parameters, and the instrumental parameters are solved independently for each reference great circle by a least-squares process.

Step 2: the resulting star abscissae for a subset of the programme stars are combined in a least-squares process, also known as the sphere reconstitution, which brings together all the different reference great circles into a single global reference system. In this process the abscissae are used as observations, and the astrometric parameters of the same stars, along with a single abscissa zero

point for each reference great circle, as unknowns. The astrometric parameters are eliminated, and the remaining system of normal equations is solved for the abscissae zero points;

Step 3: relative abscissae determined in step 1 are converted into absolute abscissae, by adjustment to the origin of the reference great-circle systems determined in step 2. Finally the astrometric parameters of each star are determined by a least-squares combination of its abscissae on different reference great circles.

The complexity of the preparations to code the programs to perform and inter-relate the above tasks, and to deal with the 24 kbits per sec of data from the spacecraft (all of which must be taken together for the final catalogue) are considerable. Nevertheless, both consortia are ready to treat the data as it comes down from the satellite after launch. Simulated detector counts, star mapper and attitude data have already passed through the entire operational software chains.

The Tycho Catalogue

The Tycho Catalogue will be an additional catalogue of lower precision astrometric data along with two-colour photometric data for some 400 000 stars down to about 11 mag, which relies on a separate 'input catalogue' of star positions provided through a collaboration with the Hubble Space Telescope Guide Star Catalogue team. The group responsible for the scientific processing of the Tycho data is referred to as the Tycho Data Analysis Consortium (TDAC).

After Launch

The European Space Operations Centre (ESOC) is responsible for operation of the satellite after launch. Observations will be prepared, the data will be acquired, archived and distributed to the data analysis teams, and the health of the satellite will be continuously monitored.

After launch, Hipparcos will be manoeuvred from its transfer orbit into its final geostationary orbit by means of an apogee boost motor. Once on station, the satellite will be despun, its spin axis will be oriented towards the Sun, then the 'scanning law' progressively acquired by means of the recognition of a known star pattern using the star mapper.

About 30 days are foreseen for payload commissioning, during which time preliminary estimates of the geometric and photometric properties of the payload, its stability as a function of time, and quantities such as the modulation coefficients, instantaneous field of view profiles and star mapper single slit responses will be determined.

Routine operations will start after this time. Within a few days it will be possible to evaluate the performances of the payload and satellite as a whole.

If the satellite performances and operations are nominal, a first full-sky catalogue of improved star positions will be available after about six months of observations. As time progresses the capability of decoupling star positions from the effects of parallaxes and proper motions will slowly improve.

By 1995, the astronomical community should be provided with the Hipparcos Star Catalogue, of unprecedented accuracy, which should have a profound influence on many aspects of astronomical research.

Summary of Expected Results

Main Experiment:	
Number of stars	~ 120 000
Limiting magnitude	B = 13 mag
Completeness	7.3–9.0 mag
Positional accuracy	0.002 arcsec (B=9 mag)
Parallax accuracy	0.002 arcsec (B=9 mag)
Proper motion accuracy	0.002 arcsec per year (B=9 mag)
Systematic errors	<0.001 arcsec
Tycho Experiment:	
Number of stars	about 400 000
Limiting magnitude	B = 10–11 mag
Positional accuracy	0.03 arcsec (B=10 mag)
Photometric accuracy	0.05 mag in B and V
Observations per star	~ 80

Statistics of the Input Catalogue

Magnitude	Number of Stars
<6	4379
6–7	8296
7–8	22539
8–9	42648
9–10	26316
10–11	7221
11–12	2142
>12	947
Total	114488

Payload and Satellite Characteristics

Optics:	
Telescope configuration	All-reflective Schmidt
Field of view	$0.9^\circ \times 0.9^\circ$
Separation between fields	58°
Diameter of primary mirror	290 mm
Mirror surface accuracy	$\lambda/60$ rms
Primary Detection System:	
Modulating grid	2688 slits
Slit period	1.2 arcsec (8.2μm)
Detector	Image dissector tube
Photocathode	S20
Sensitive field of view	38 arcsec diameter
Spectral range	375–750 nm
Sampling frequency	1200 Hz
Star Mapper (Tycho) System:	
Modulating grid	4 perpendicular to scan 4 at 45° inclination
Detectors	Photomultiplier tubes
Phtocathode	Bialkali
Spectral range (B)	$\lambda_{\text{eff}} = 430$ nm, $\Delta\lambda = 90$ nm
Spectral range (V)	$\lambda_{\text{eff}} = 530$ nm, $\Delta\lambda = 100$ nm
Sampling period	600 Hz
Satellite Parameters:	
Launch mass	1140 kg
Power requirements	295 W
Uplink data rate	2 kbits/sec
Downlink data rate	24 kbits/sec

Industrial and Scientific Organisation

Project Responsibility	European Space Agency
Industrial Prime Contractor	MATRA (F)
Satellite Procurement & Integration	AERITALIA (I)
ESA Project Manager	H. Hassan
MATRA Project Manager	M. Bouffard
AERITALIA Project Manager	B. Strim
ESA Project Scientist	M. Perryman
INCA Consortium Leader	C. Turon (Meudon)
NDAC Consortium Leader	E. Høg (Copenhagen)
FAST Consortium Leader	J. Kovalevsky (Grasse)
TDAC Consortium Leader	E. Høg (Copenhagen)

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European Space Agency, 8/10 rue Mario Nikis, 75738 Paris Cédex 15, France

MAPPING STARLIGHT FROM THE DEPTHS OF TIME

Cosmos, a word of Greek origin, was first used to describe beauty, harmony. To the Greeks it also came to mean the observed universe regarded as an orderly collection of stars and planets.

On a clear, dark night, the sky, to the naked eye, presents a dramatic sight : the Milky Way, a diffuse band of light made up of millions of stars stretching across the celestial sphere.

As early as 120 B.C. the Greek astronomer Hipparchus measured the lunar parallax, and hence the distance from the earth to the moon. Parallax is the apparent displacement of a celestial object when seen from two widely displaced points - this is a very small angle measured in arc seconds that a baseline connecting the two points would subtend at the object. Knowing the parallax of a star enables astronomers to calculate the distance of that star from the Earth.

Hipparchus, one of the greatest pioneers in this field, drew the first star map and by comparing this with observations made by his predecessors, he was able to establish that the Earth's rotation axis slowly changes its direction in Space. His observations were based on measurements made with the naked eye, with a power of resolution limited to about one minute of arc.

Two thousand years later, the European Space Agency has developed the first satellite devoted to the precise measurements of the positions, the motions and parallaxes of more than a hundred thousand stars.

The European satellite named Hipparcos (High Precision Parallax Collecting Satellite) after the Greek astronomer will have a power of resolution of about 0.002 arc seconds, that is a resolution more than a thousand times higher than that of the naked eye.

Data obtained from the new satellite will enable scientists to discover more about our solar system and our galaxy and the physical properties of the stars and how they change and move throughout their lives. In fact Hipparcos will be a major step in our understanding of the very structure and evolution of our galaxy.

Certainly over the last hundred years astrometry, that is the branch of astronomy which deals with the precise measurements of positions and movements of celestial bodies, has advanced due to the improvements made in ground based telescopes. However, even the very big telescopes that are being built today will have a limited power of resolution because they are submitted to the effects of atmospheric turbulence.

Comparing data obtained from observatories around the world shows systematic differences due to the variations in refraction which cannot be studied accurately, and thus be taken into account.

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Dr. Michael Perryman, ESA's project scientist for Hipparcos explains : *"The effects we are looking for are really extremely small. And we can really still only measure with a certain precision the distances of the stars nearest us. While progress is still being made from the ground, the Earth's atmosphere presents a formidable barrier to astrometrists. Placing a satellite above the atmosphere removes this problem and also allows scientists to exploit a carefully controlled thermal environment, beyond the Earth's gravitational field which causes instrumental deformations on any telescope on the ground. From Space, the satellite will also be able to view the whole sky, something which is impossible for a ground-based telescope".*

Already in the 1960's astronomers realized that the only way to progress in astrometry would be to go beyond the atmosphere into Space. The first proposal for a Space astrometry mission was submitted in 1966 by a Frenchman, Prof. Pierre Lacroute, working at the Strasbourg Observatory.

Star Gazing in a Spin

Data collected by Hipparcos will be transmitted immediately to Earth as it cannot be stored on board.

ESA's European Space Operations Centre (ESOC) in Darmstadt, Federal Republic of Germany, will receive the data. During the first month it will be collected by three stations of the ESA world-wide tracking network in Kourou (near the launch site) French Guiana, Malindi, on the Indian Ocean coast of Kenya, and in Perth, Australia.

All critical operations will be monitored from ESOC's multi-mission control centre in real time. After the first month, data will be beamed down to the Odenwald station near Darmstadt and transmitted to ESOC. (ESOC is responsible for all satellite operations on a continuous basis throughout the 2.5 year mission).

24,000 bits of data per second will be recorded, and every single bit is like a piece of a giant puzzle in that it yields its share of information and must be processed with the same care so that each element contributes to the final solution.

Because of the importance and extraordinary complexity of this task, ESA has appointed two scientific consortia to process the data. They will work in parallel so that there will be a full and independent cross check of the two star catalogue.

Spinning slowly in space, the satellite will sample five of six stars at once; Throughout its two and a half year mission, Hipparcos will scan the sky from a geostationary orbit 36,000 km above the Earth. It will rotate around its axis a little more than once every two hours. This axis of rotation will gradually and constantly change direction so that the optics of the satellite will be kept at a constant angle to the Sun.

Stars get their "Who's Who"

By 1993 Scientists will have two complete star inventories : the Hipparcos and Tycho catalogues.

1,000 billion bits of satellite information recorded on magnetic tape and processed will be combined to make the Hipparcos Catalogue, a compilation of 100 thousand stars uniformly distributed over the celestial sphere. White dwarfs, red giants like Beltelgeuse and Antares, or Mira (Latin for wonderful), a star in the constellation of Cetus that sometimes vanishes from sight and is sometimes as bright as the polar star, will be listed in the Hipparcos catalogue. The positions, parallaxes and annual proper motions of each star will be recorded with an accuracy of about 2 milliseconds of arc.

The Tycho Catalogue will give the positions of some 400,000 stars with less accuracy but with detailed two-colour photometric information for each star.

Hipparcos Project Manager Dr. Hamid Hassan points out that *"The catalogue will be used for decades by astronomers to increase our knowledge of the universe and provide living proof of the value of European cooperation in Space for future generations"*.

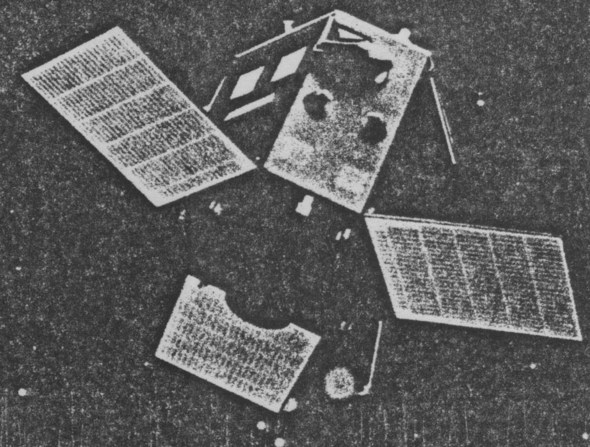
The Hipparcos satellite is prepared for launch

After final flight acceptance tests were carried out in the Agency's Large Space Simulator at ESTEC, the communications links between the satellite and the ESOC ground control station were verified, and the satellite then transported from Toulouse to the launch site at Kourou by air. Alignment tests carried out at the launch preparation facilities confirmed that the satellite did not suffer during the transport. Final operations carried out at Kourou (such as the filling of the hydrazine tanks responsible for the attitude control once the satellite is in orbit, and arming of the apogee boost motor, responsible for injecting the satellite into its circular geostationary orbit) bring to an end the 9 year industrial development of the Hipparcos satellite. It is now ready for launch.

European Space Agency, 8/10 rue Mario Nikis, Paris Cedex 15, France
Editor : Beatrice Lacoste ☎ 42 73 72 90

Slides and black and white prints available on request ☎ 42 73 71 55

HIPPARCOS - Satellite Parameters



Fields of view	: 0.9 degrees square
Basic angle	: 58 degrees
Diameter of primary mirror	: 290 mm
Spectral range	: 375– 750 nm
Mass	: 1140 kg
Launch vehicle	: Ariane 4
Operational orbit	: Geostationary
Operational lifetime	: 2.5 years
Downlink data rate	: 24 kbits per sec

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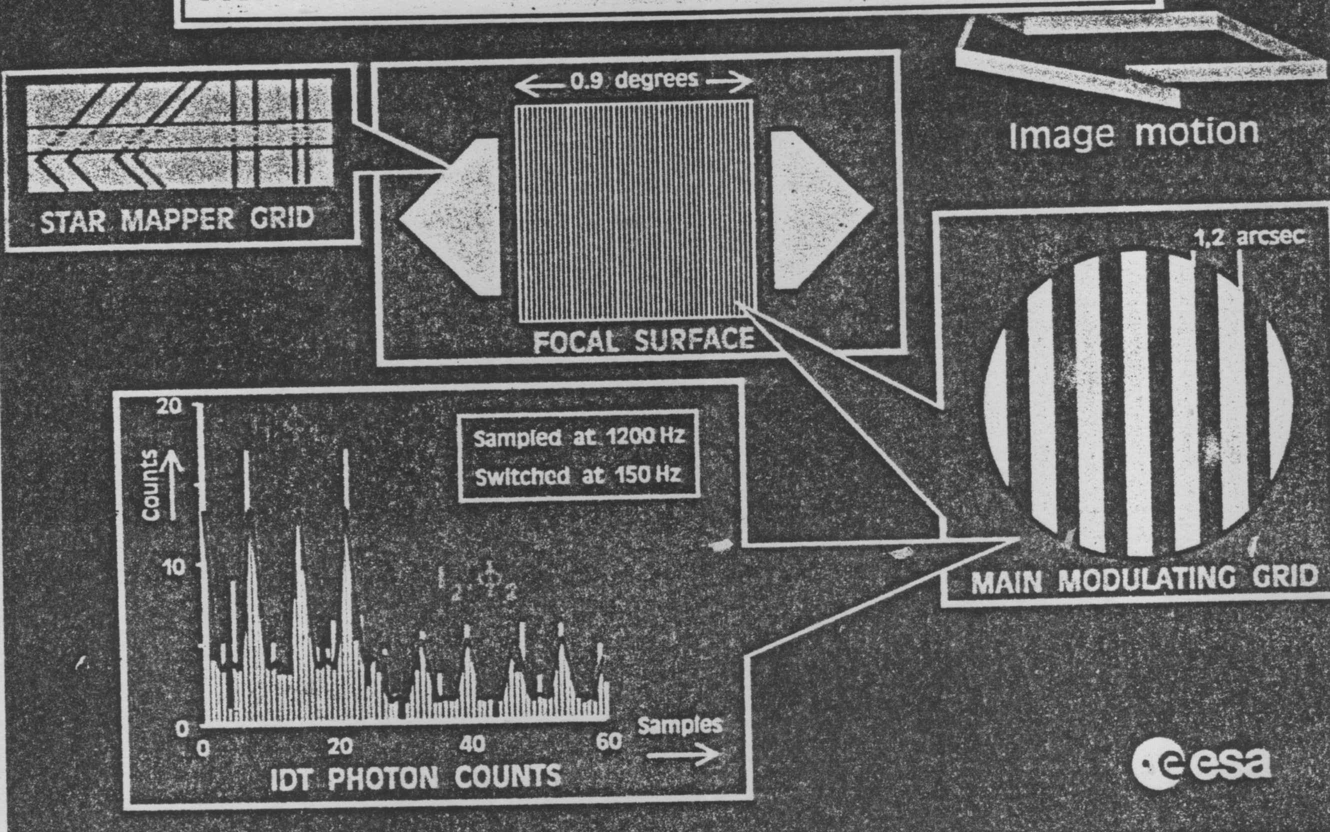
HIPPARCOS - Phase determination



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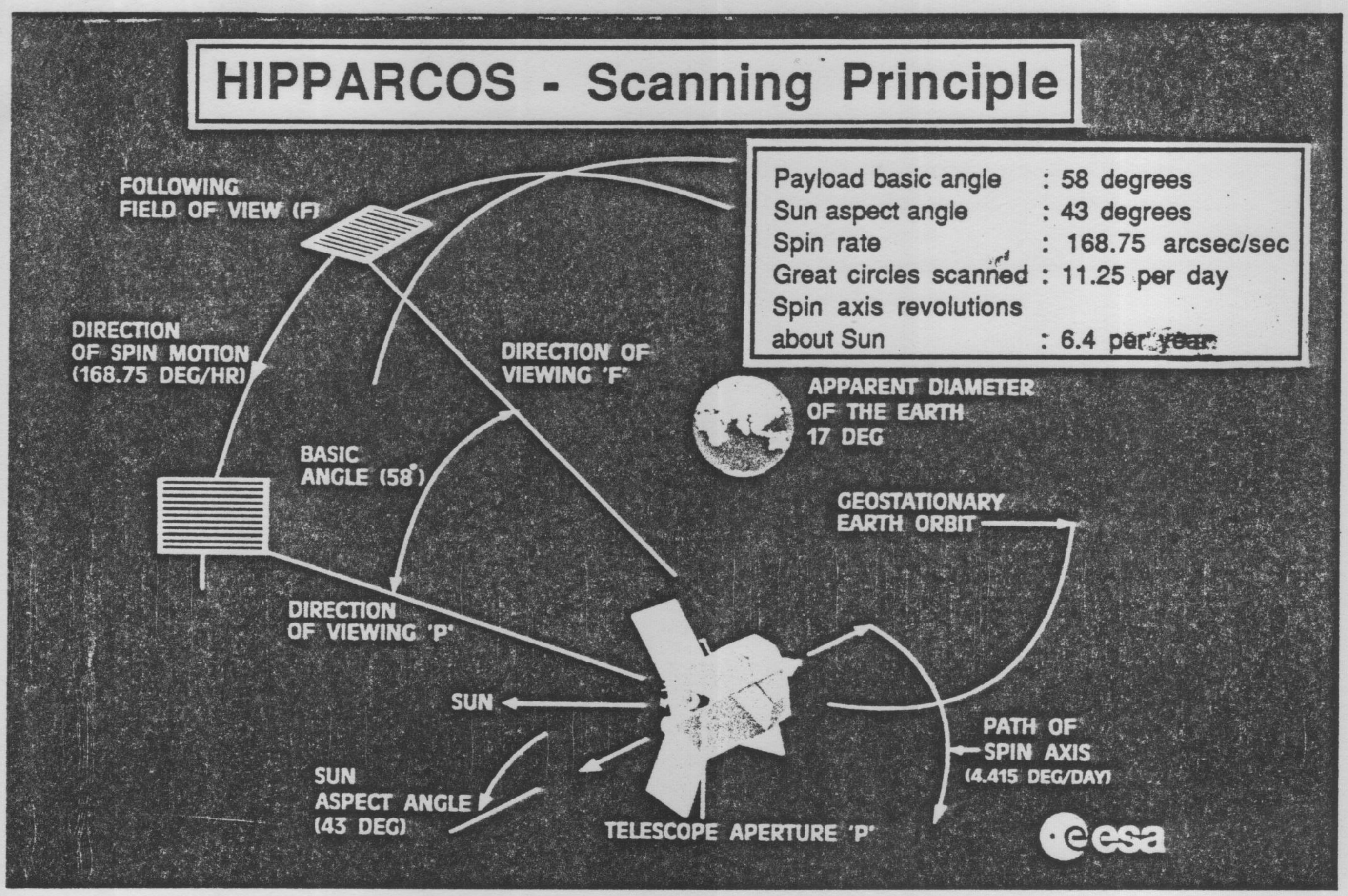
HIPPARCOS - Scanning Principle
Payload basic angle : 58 degrees
Sun aspect angle : 43 degrees
Spin rate : 168.75 arcsec/sec
Great circles scanned : 11.25 per day
Spin axis revolutions
about Sun : 6.4 per year
FOLLOWING
FIELD OF VIEW (F)
DIRECTION
OF SPIN MOTION
(168.75 DEG/HR)
DIRECTION OF
VIEWING 'F'
APPARENT DIAMETER
OF THE EARTH
17 DEG
BASIC
ANGLE (58°)
GEOSTATIONARY
EARTH ORBIT
DIRECTION
OF VIEWING 'P'
SUN
PATH OF
SPIN AXIS
(4.415 DEG/DAY)
SUN
ASPECT ANGLE
(43 DEG)
TELESCOPE APERTURE 'P'
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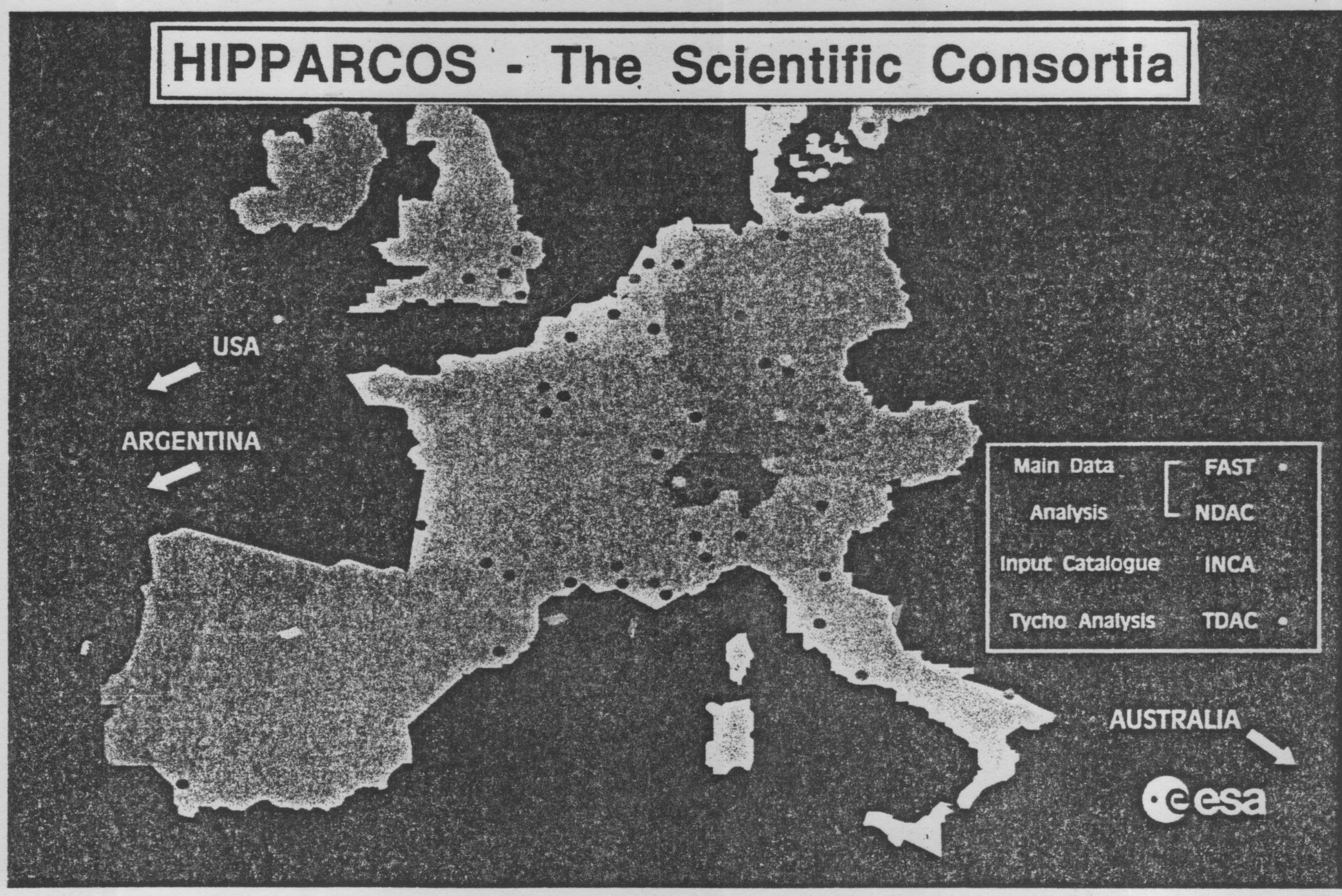
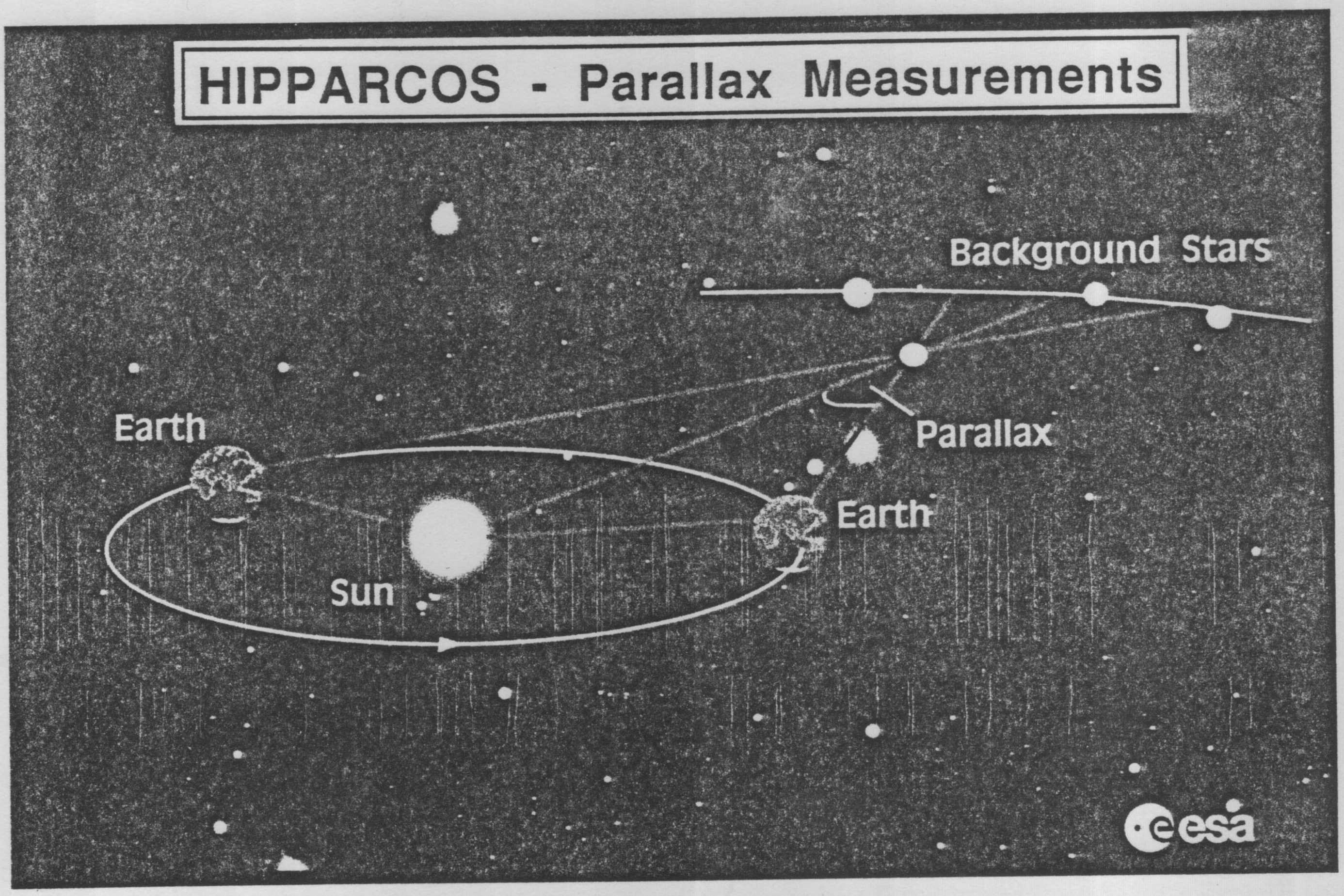
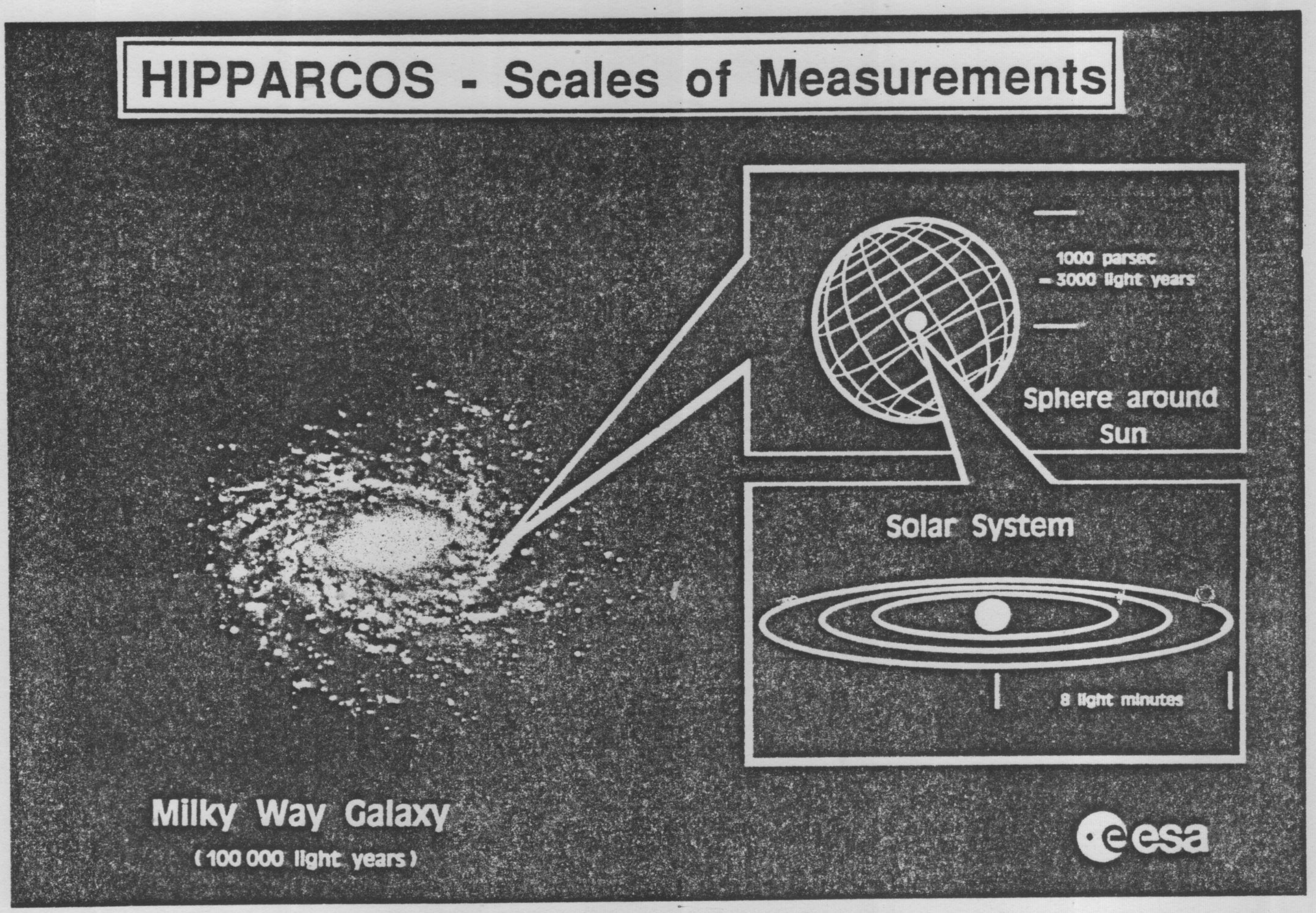
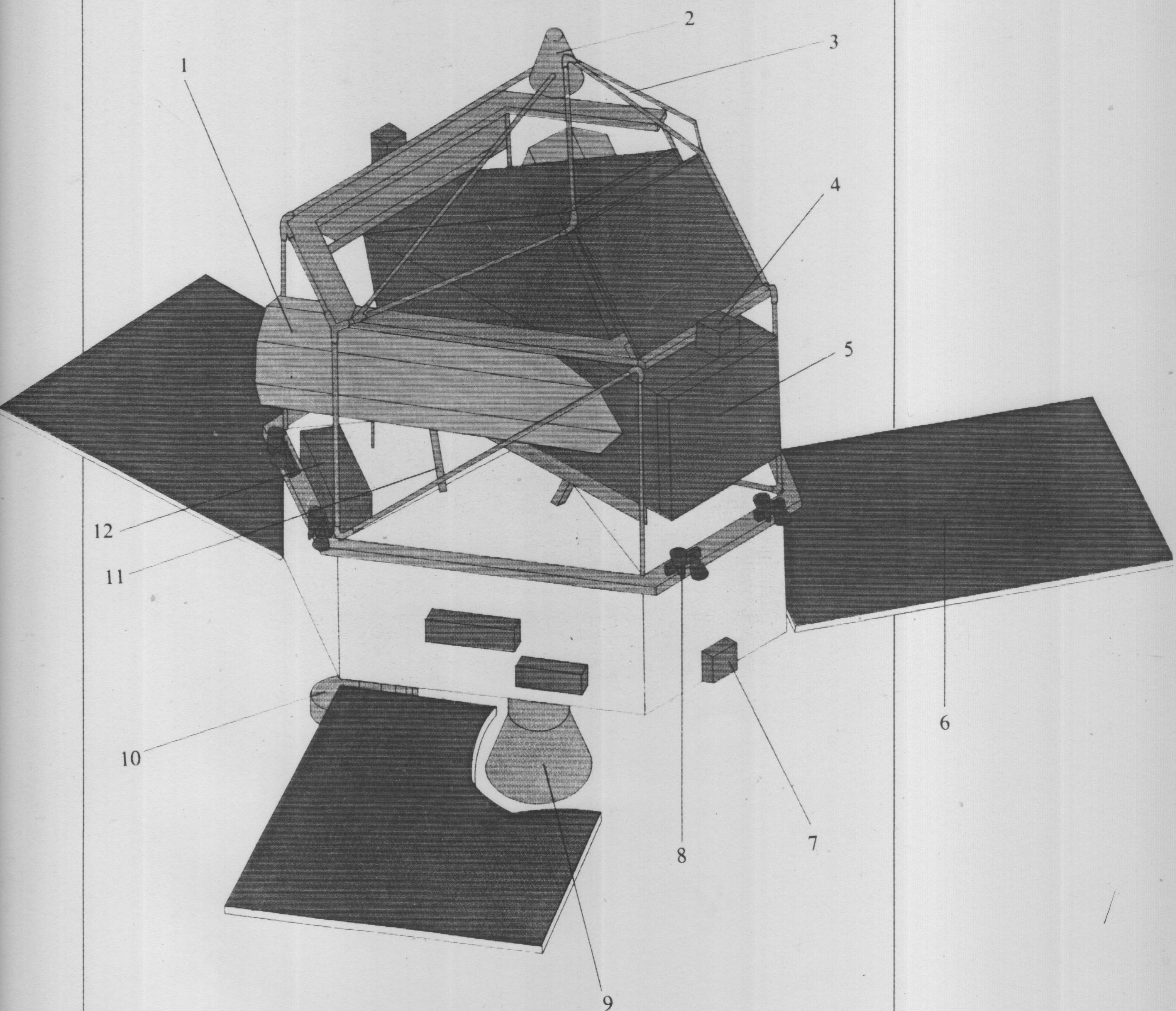

HIPPARCOS - The Scientific Consortia
USA
ARGENTINA
Main Data
Analysis
FAST
NDAC
Input Catalogue
INCA
Tycho Analysis
TDAC
AUSTRALIA
esa


HIPPARCOS - Parallax Measurements
Background Stars
Earth
Parallax
Earth
Sun
esa


HIPPARCOS - Scales of Measurements
1000 parsec
= 3000 light years
Sphere around Sun
Solar System
8 light minutes
Milky Way Galaxy
(100 000 light years)
esa

Hipparcos (High Precision Parallax Collecting Satellite). This satellite is built by the ESA to carry out a census of 100,000 stars, measuring the respective positions of each one to an accuracy of between 1/1000–2/1000ths of a second of arc. The Hipparcos satellite will be launched in 1988, and placed in a geostationary orbit. Weighing, in orbit, 1,058 lb (480 kg), it will have a planned technical life of 2½ years. 1 – observatory external protection; 2 – cardioid antenna; 3 – supporting structure; 4 – solar acquisition sensors; 5 – structure containing payload; 6 – solar cell panels; 7 – Earth/Sun infra-red sensor; 8 – spin/despin and stabilization thrusters; 9 – propulsion unit; 10 – solar acquisition sensor; 11 – interface structure between payload and space vehicle; 12 – electronic service unit for payload.



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The Ariane Thread
From the Jungle to the Stars

Until 1954 this strip of savannah and jungle between the Amazon forest and the Atlantic Ocean was infested with malaria and had only two connotations : deportation and exile for French convicts and gold fever attracting gold-diggers from nearby Brazil and Europe.

Today the Kourou Space Centre in French Guiana launches the European vehicle Ariane. The new launch site ELA-2 (from the French "Ensemble de lancement Ariane") towers twenty storeys high over the lush vegetation. Construction of the new site began in mid-1981 under a programme of the European Space Agency to launch the Ariane 2, 3 and 4 versions. The first Ariane 4 was launched from ELA-2 on June the 15 th.

In 1984, the Kourou Space Center was at the top of the Western league in terms of the number of commercial satellites put into orbit. In 1985, ELA-2 was completed.

Back in 1964 CNES, (Centre National d'Etudes Spatiales) chose Kourou as a launching site because it ideally satisfied the two essential requirements of a launch pad: fuel saving and safety.

Kourou, at a latitude of 5.3° north on the equator makes it possible to send into orbit, at an equal cost, a payload 17% heavier than the equivalent launched from Cape Canaveral in Florida. This is because Kourou is nearer the Equator : the Earth rotates from west to east and the velocity at the surface of the Earth is equal to zero at the poles and increases to a maximum as you get closer to the Equator. Consequently, at the Equator, 6% of the velocity required for a load to go into orbit and not fall back on Earth is free.

The other important consideration is safety - Space centres are usually situated on the Eastern seaboard of a continent or island so that the first stages of a launch vehicle and, in the event of a crisis, the vehicle itself do not fall on an inhabited area. From Kourou, a space vehicle launched in an easterly direction will not encounter land before Africa and, in a northerly direction, before Canada.

However there are a few drawbacks because of some inhospitable aspects of the environment. The high degree of humidity and the possible corrosion of metal structures by salinity for instance. Tiny insects, called builder flies, one of the 40,000 different species in a single hectare of Amazonian jungle, make their nests on the vehicle and secrete a substance which they use as a binding material and which effectively blocks all the air vents. But engineers found a simple solution to keep them away by constantly blowing air from inside the launcher.

The range extends along a 15 km coastal stretch between Kourou, which used to be a small fishing village, and Sinnamary, a sleepy river crossing.

Various facilities for remote sensing and telemetry are located on the Montagnes des Pères where Jesuit missionaries once settled, and on one of the îles du Salut where convicts were sent.

The ELA-2 pad is located south of the launch control centre. Its structure is completely different from ELA-1 where launchers are assembled, integrated and connected to the umbilical tower in the building which is withdrawn at the moment of the launch.

The first of the Ariane 4 series (Ariane 401) was assembled in the new ELA-2 building, twenty storeys high (80 m) and then, on April 29th 1988, conveyed to the launch base, a distance of 950 m away, on a trolley that glides along rails: this took about 45 min. For this "roll-out" the weather forecast is very important: in the case of Ariane 4 it was advanced because a strong wind could topple the launcher.

Up to ten launches a year

At the launch base Ariane 4 was coupled to the umbilical tower which is 74 m high, shelters the equipment and provides fluid links between the launcher and the ground facilities. The two cryogenic arms extend to link up with the third stage of the launch vehicle.

A servicing gantry is advanced in its forward position to allow the following operations to take place : assembly of the solid propellant boosters, final launcher check-out, assembly of the payload and fairing. Before launch it retracts.

These operations prior to count-down take about two weeks. In this way, by having separate assembly and servicing buildings, work can begin on a new vehicle before the previous one has been launched so that about ten launches a year can take place. Time is saved, and operational costs reduced.

Another launch site, ELA-3 is planned for Ariane 5 in 1995 and for the Hermes Spaceplane, which it will launch.

Immediately after the launch of Ariane 4 next June, control of the flight will be handed over to the large technical centre 10 km away from the launch pad. Separated from it by wild green savannah teeming with multi-coloured butterflies, humming birds and ibises, the technical centre handles the exchange of flight information with tracking stations at Belem and Natal in Brazil and Ascension Island in the Atlantic. The Kourou tracking station covers the first nine minutes of the flight.

On its demonstration flight Ariane 4 will carry three satellites into orbit, Meteosat P2, launched by ESA for weather forecasting (P2 will act as gap-filler until the launch of a new improved model at the end of the year), a communications satellite, called PANAMSAT and a small amateur radio communications satellite.

The Ariane programme is Europe's response to the increasingly competitive market of launch vehicles: from 1980 to 1995 five versions of Ariane will be available, increasing the payload in geostationary transfer orbit from about 2,000 kg to about 6,800 kg. Since 1973 Ariane has been financed by the European Space Agency.

A boost for multiple launches

Ariane 4, a very versatile three stage vehicle, was designed to compete on the international market : the launcher offers a choice both of propellant - for the strap on boosters either solid or liquid and of the actual number of boosters - two or four. The first types are loaded with 9.3 tons of solid propellant and have a thrust potential of 66 tons.

This way Ariane 4 can be adapted according to which satellites are ready to be launched, and thus the cost will vary according to the payload.

Looking to the near future, Ariane 5 will be more powerful and even more versatile : it will carry either automatic satellites, space station elements, or a crew into orbit.

The choice of this launcher is based on cost and safety considerations. For crewed missions the Hermes Spaceplane, equipped with its own in-orbit propulsion system will be fitted on top of Ariane 5 - the first manned flight is planned for the late 1990s. Space exploration and exploitation is one of the most significant changes of this century, one that has had the greatest impact on our lives.

From Kourou satellites are sent tens of thousands of kilometers from the Earth to relay telephone conversations, carry television programmes to homes throughout continents, to observe the land and oceans and to monitor the weather and the environment.

The contrast between the Amazonian Indians, who live only a few tens of kilometers from the Guyanese Space Centre, and modern civilization is tremendous: the Indians measure distances in paddling time, or by the number of bends in the river.

This contrast also shows what a long way humanity has gone, but also how ingenious man has always been: man is distinguished from other animals by his imagination, his ability to change his environment: he plans, invents, makes new discoveries. This series of inventions from dug-out canoes and blow-pipes with a range up to 30 m, to

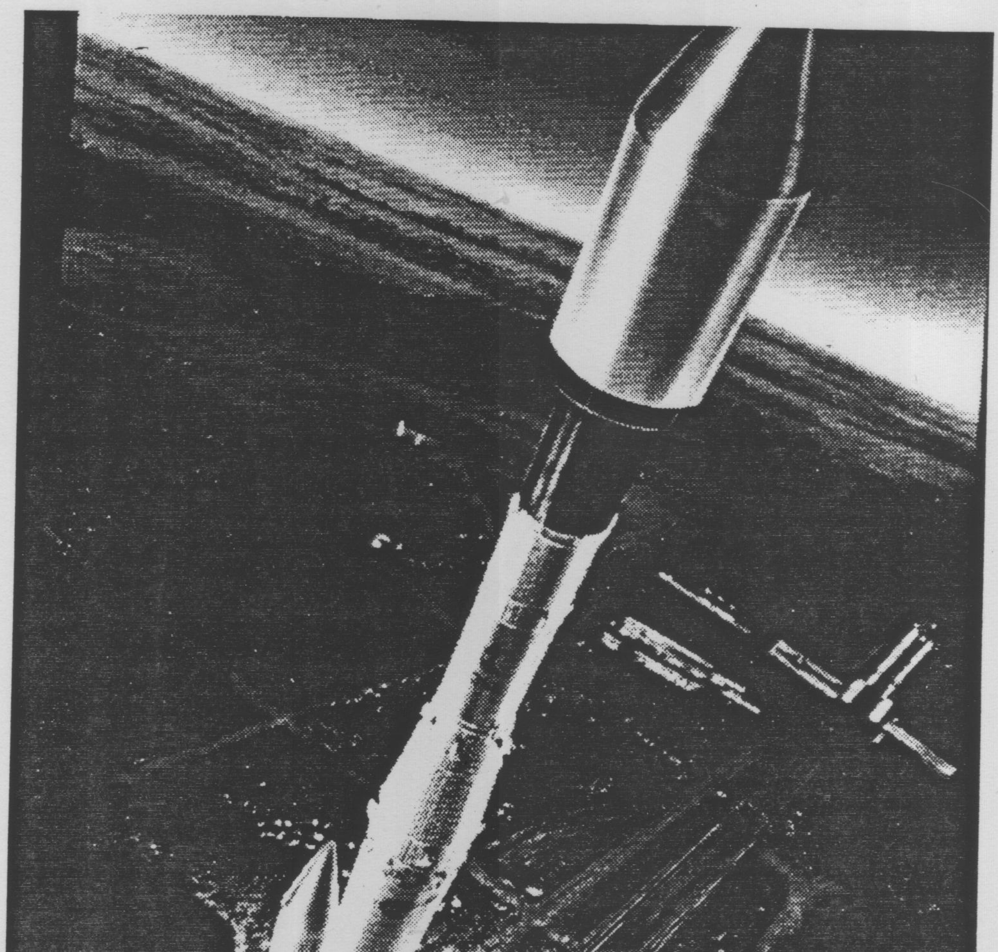
the Ariane launchers represents a cultural evolution made possible by man's imagination, his commitment to working together as one.

As the French philosopher Henri Bergson said : "Man's body now stretched to the stars needs a supplement of soul".

European Space Agency, 8/10 rue Mario Nikis, Paris Cedex 15, France
Editor : Beatrice Lacoste ☎ 42 73 72 90

Slides and black and white prints available on request ☎ 42 73 71 55

IMAGE



Ref: AR4-1

An artist's impression of the launch of Ariane 401 from the Centre Spatial Guyanais, CSG, at Kourou, in French Guyana. CSG is situated 5 north of the equator and has a launch angle of 104 .

This makes Kourou one of the most efficient launch sites in the world.

european space agency
8-10, rue Mario Nikis, 75738 Paris Cedex 15, France

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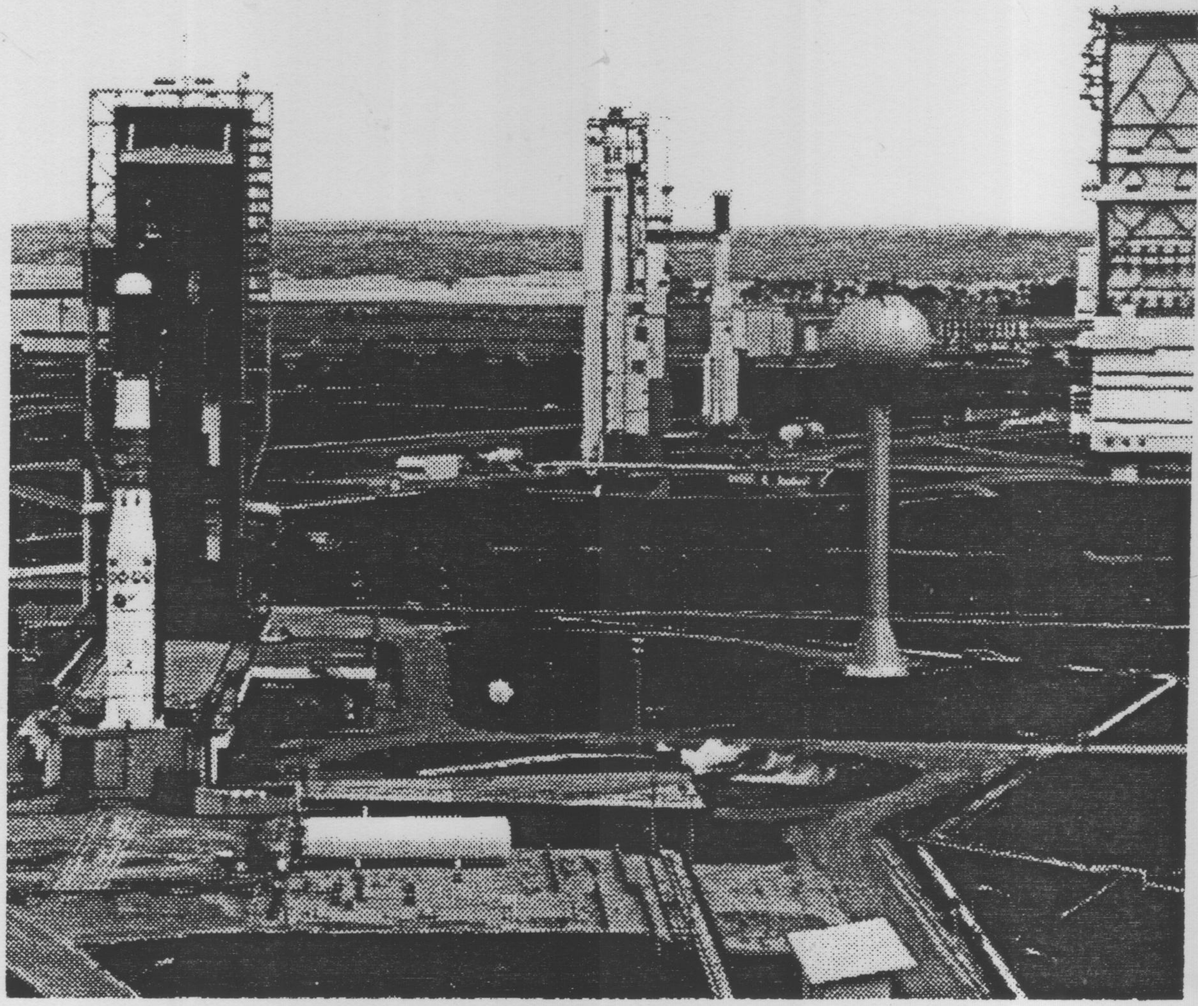

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The first and last image of its kind. In the foreground, ELA-1 and Ariane V23 awaiting launch. In the centre, ELA-2 with Ariane 401 awaiting launch. In 1989, ELA-1 will be closed as construction starts on ELA-3, in preparation for Ariane 5, the new ESA launch vehicle for large commercial payloads and the spaceplane, HERMES.

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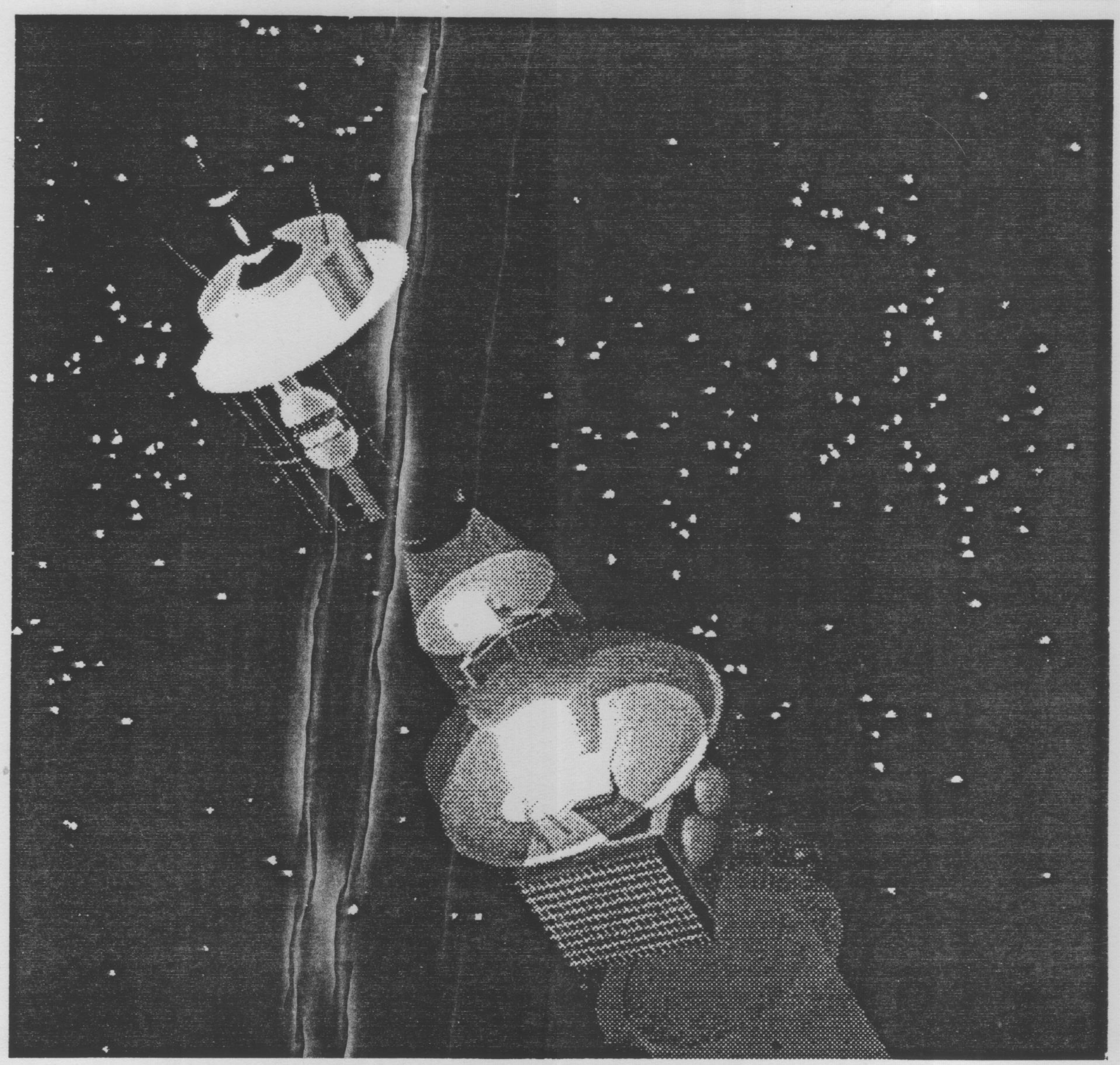

Ref: AR4-12

Three satellites will be launched by Ariane 401. In order of descent they are:
METEOSAT P2, the third ESA meteorological satellite.
AMSAT IIIC, an amateur radio satellite. PAS 1, [Pan American Satellite] a communications satellite, the first to operated by a private company, outside INTELSAT.

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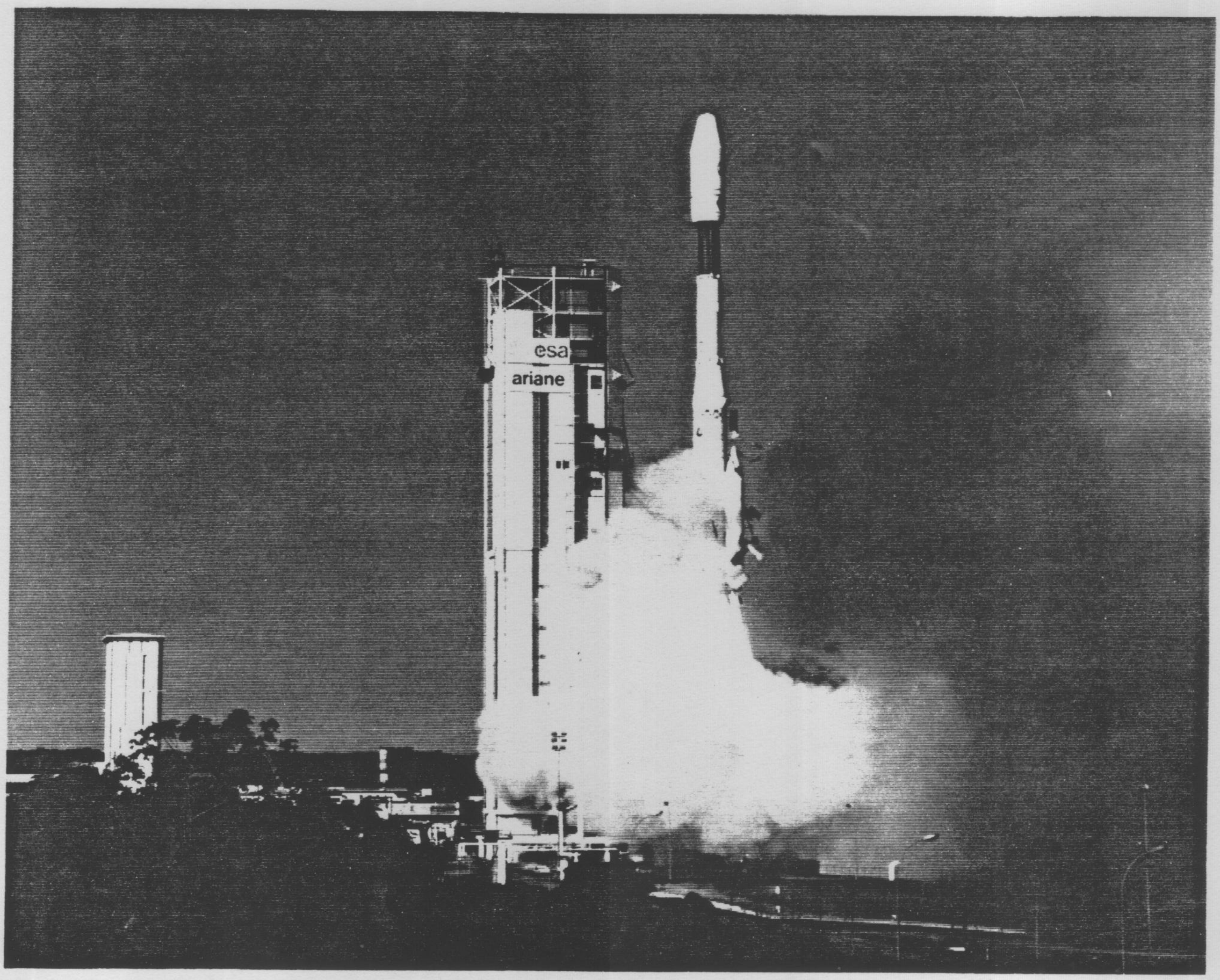
IMAGE



ARIANE 401

At 11:19am, (UT), on the 15th June, 1988, the European Space Agency successfully launched Ariane 401 on its maiden flight.

"Thanks for the lovely ride," commented Fred Landman, President of Pan American Satellite, after Ariane 401 had successfully deployed all three of its satellites: ESA's METEOSAT P2, Pan American Satellite 1 and AMSAT IIIC.

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BACKGROUND INFORMATION ON ESA

When and how was ESA set up ?

The European Space Agency is a R&D organisation responsible in Europe for all civilian space activities. It was created de facto in 1975 by merging two forerunners, ELDO (European Launcher Development Organisation) and ESRO (European Space Research Organisation), both of which came into being in 1964. Thirteen countries are members of ESA.

ESRO was very successful in the development of several scientific satellites. ELDO developed the Europa 1 and 2 launchers, drew up plans and built the Europa launch pad in French Guiana. However, all ELDO activities stopped before the Europa 3 launcher was built.

What are the Agency's main activities ?

Since its creation ESA has successfully developed three main programmes lines : scientific and application satellites such as Giotto or Meteosat, a manned space flight laboratory for microgravity research - Spacelab - in cooperation with the United States, and the European launcher family Ariane. Today new major programmes are being undertaken on the basis of the European long-term space plan : Ariane 5, the Hermes spaceplane and the Columbus elements to be part of the International Space Station.

How was Ariane developed ?

The Ariane 1 development programme was decided in the framework of ESRO in 1973 and later came under the responsibility of ESA. On the strength of its expertise in launcher systems,the Centre National d'Etudes Spatiales (CNES), the French national space agency,was entrusted by ESA with the technical and financial management of the Ariane development programmes. ESA retained overall authority.

How is Ariane marketed ?

The first Ariane 1 launch took place on Christmas Eve 1979. In 1980 several ESA Member States entrusted Arianespace - a private-sector firm under French law with European shareholders - with the production, launching and marketing of the Ariane operational launcher, ESA remaining responsible for the development of new configurations such as Ariane 5.

What is the Guiana Space Centre (CSG) ?

The Guiana Space Centre (CSG) was built by France for its national rocket programmes, such as Véronique and Diamant. France then offered to host the launch range for ELDO's Europa launcher. The launch pad built by ELDO was taken over by ESA, modified for the Ariane launcher and renamed ELA, the Ariane launch complex.

How is the CSG run ?

The Guiana Space Centre is run by CNES, with ESA Member States contributing a substantial proportion of the costs. On the site of the CSG, the European Space Agency has built ELA1 and ELA 2, and is preparing ELA 3. The two launch pads ELA 1 and ELA 2 are used by Arianespace, but belong to ESA, Arianespace being responsible for their maintenance and paying fees to ESA.

In addition CNES operates a launch pad for French sounding rockets.

An entry for the "Guiness book of records" ?

The launch tower of the ELA 2 complex weighs as much as the Eiffel Tower, but it is mobile. This makes it the largest European-built mobile building.

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8-10, rue Mario Nikis - 75738 Paris Cedex 15 - France
Tél. : 42.73.72.91 - Télex : ESA 202746